SOLAR THERMAL INSTALLATIONS
FOR HOT WATER PRODUCTION IN THE HOTEL COMPLEX “DOBRUDZHA” ALBENA RESORT

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1. INTRODUCTION

One of the goals of Albena Complex development is improving energy technologies supplying the diverse tourist services of the complex. One of the prerequisites for Albena prosperity is preserving the environment in the resort surroundings. Energy production in its conventional forms is connected to contamination of air and soil. Using only electricity to satisfy the needs of heat and conditioning is not economical in most cases. The renewable energies are one of the possibilities to improve the heat production technologies. It is proved that the climatic conditions in Bulgaria, including those at the Black Sea coast, are suitable for economically viable hot water production from solar installations.

2. MAIN TASKS

- Analysis of the special features and technical condition of the existing installations for domestic hot water preparation in Dobrudzha Complex;
- Analysis of hot water requirements in short and long terms;
- Synthesis of solutions for satisfaction of hot water requirements with solar installations;
- Economic analyses of the variants for prognosis of investments, operational costs and profit for the installation life-time.

3. HOT WATER CONSUMPTION FORECAST

The hotel complex disposes with 600 beds. The average daily hot water consumption is forecasted in accordance with the existing norms and with the information from the administration on the average monthly occupancy. According long-term measurements the hotel restaurant requires 7200 l/day. The third consumer is balneotherapy centre with polyclinic. The variety of balneotherapy procedures and the variable needs of hot water for each procedure hamper the definition of norms for consumption. According a statistical assessment by the technical staff, the relative share is 14 % of the total for the hotel. There are two swimming pools functioning at the hotel with surface of 300 m^2 (for adults) и 30 m^2 (for children). The average daily water consumption is determined based on 12 h operation of the pools.

The forecasted maximum total hot water consumption is 99 360 l/day. Fig.1 shows the diagram of the relative hot water consumption during different months of the year.

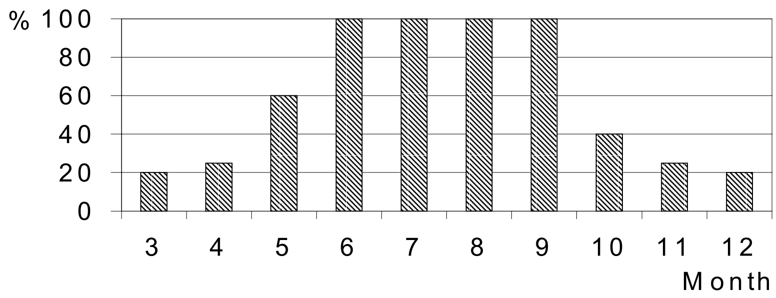

Fig. 1. Average daily relative hot water consumption

Now the water is heated by a boiler house on liquid fuel, supplying three substations – for the hotel building and the restaurant (SS №1), for the polyclinic and balneotherapy centre (SS №107) and for the swimming pools (SSб). In substations №1 and № 107 there are tanks for heated water accumulation with total volume of 18 m^3 and 6 m^3. In both substations there are mounted water-water high-speed heaters of type ВВП. They work in regime: primary heat carrier 75/45°C and secondary flow (heated water) 12/50°C. In substation "Pools" there are no accumulators for the heated water.

4. SOLAR WATER HEATING INSTALLATIONS

When designing the solar installations the following factors have been considered: type of hot water consumers, period of system operation, distance from the consumers, existing sub-stations, pre-determination of the supplementary heat supplier – boiler-house. Recommendations and results from large solar thermal installations have been used.

It is foreseen an indirect active solar system for hot water preparation with heat accumulators. The solar collectors have been cooled by a water solution of propylene glycol. The absorbed energy is transported via a heat exchanger to a heat accumulator – first stage. The function of heat accumulator – second stage, will be performed by the existing hot water preparation system. The scheme of Fig.2 includes also an intermediate plate heat exchanger, circulation pump and automatic control system for the solar installation operation.

The diversity of consumers' specifics and the dynamics of the hotel occupancy require to be assessed different solutions for solar installations. The central positioning of the hotel building and its much bigger height compared to the rest of the complex limit the choice for sites for solar collector montage. The preliminary investigation on shadowing of the neighboring roofs allows using with acceptable compromises three limited dimension sites (fig. 3 and 4).

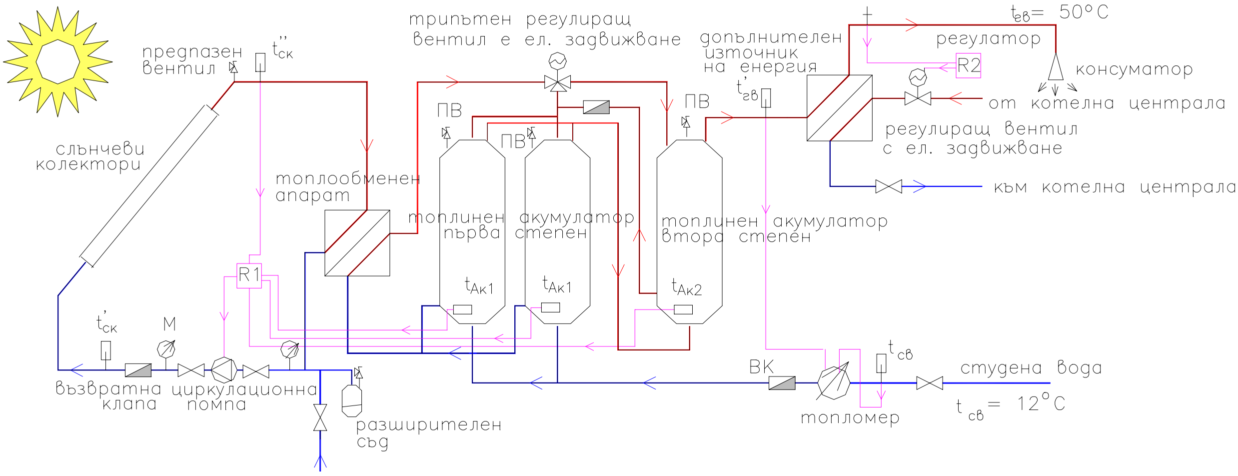

Fig. 2. Structural design of solar installation with supplementary energy source – boiler house

Solar collectors with the following characteristics have been used in the investigation:

(FC) flat solar collectors with selective plating of the absorber, overall losses coefficient of 5.0 W/m^{2}C, relative absorber capacity of 0.750, collector slop - 30^o (summer operation) or 43^o (all year round operation), collector azimuth - (south=0) - 0^o.

(VC) vacuum solar collectors with overall losses coefficient of 2.0 W/m^2.C, relative absorber capacity of 0.82, collector slop of 43^o, collector azimuth (south=0) – 0^o.

Four systems with different structures have been included in the investigation.

System 1. Flat solar collectors, grouped in three collector fields. Collector field №2 is connected to an installation operating all year round. Collector fields №1 and №3 serve installations operational only during the tourist season.

System 2. Flat solar collectors, grouped in two collector fields. Collector field №2 is connected to the installation operating all year round.

System 3. Solar collectors, flat and vacuum, grouped in three collector fields. In collector field №2 the vacuum collectors operate all year round. Collector fields №1 and №3 will work only during the tourist season.

System 4. In collector field №2 there are vacuum collectors mounted for all year round operation. Flat collectors in filed №1 work only during the tourist season.

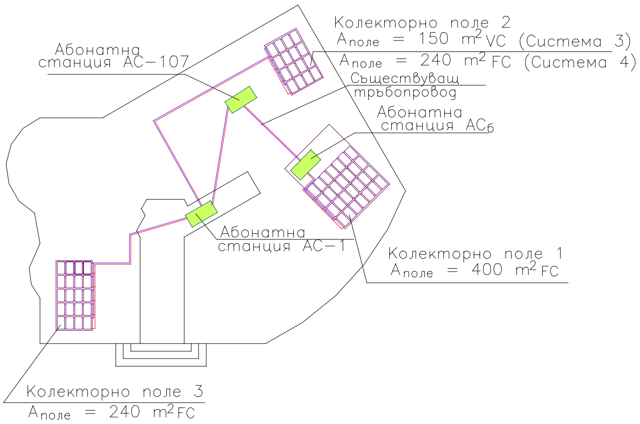

Fig. 3. Collector fields for systems 1 and 3

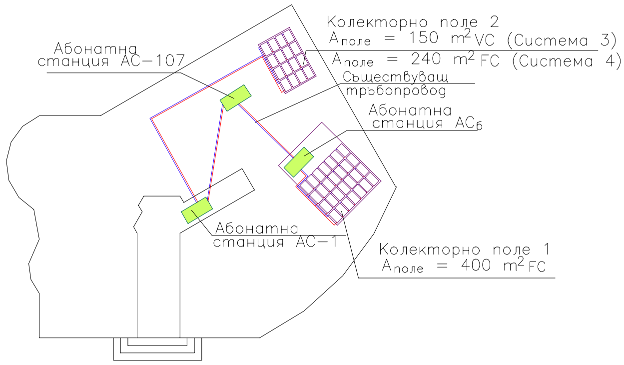

Fig. 4. Collector fields for systems 2 and 4

5. ANNUAL HEAT PRODUCTION

The analyses have been performed using a software, based on the developed by University of Wisconsin, Solar Energy Laboratory, USA, F-chart method for long-term assessment of active solar thermal systems. Integral data are used for the real climatic conditions in Varna. The close distance between Varna and Albena Resort and the similarity of the geographic situation give us the justification to consider that there should not be any significant differences in the integral climate characteristics.

Basic is the installation for all year round (from March to December) operation. The load schedule by month is shown on Fig. 5. Solar installations with different areas have been investigated – from 100 to 400 m^2 at flat collectors and from 90 to 300 m^2 at vacuum collectors. Coefficient of annual coverage reaches 0,43 at solar installation of 400 m^2.

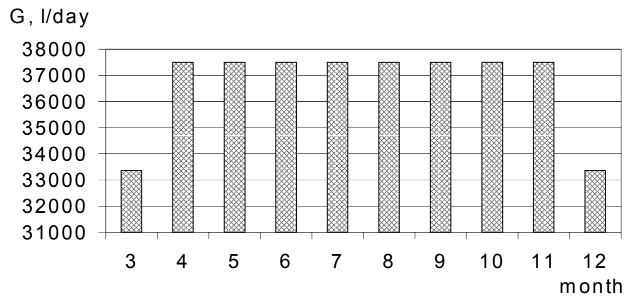

Fig. 5. Average daily hot water consumption – basic installation

The size of the field is limited by the roof surface that is not being shadowed by the high building.

The load schedule of the peak installation by month is shown on Fig. 6. Variants have been examined with flat collector area of 400 to 1000 m^2. The coefficient of annual coverage reaches 0,85 at solar installation with 1000 m^2 field.

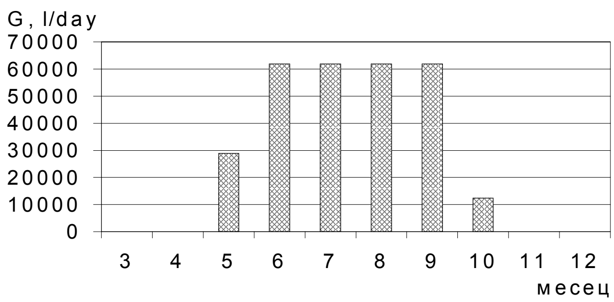

Fig. 6. Average daily hot water consumption – peak installation

6. INVESTMENT EFFICIENCY ASSESSMENT

The economic appraisal has been made for comparison of alternative solutions and choosing the optimum variant. The following methods have been used: Pay-back period method; profit for the life-time method; method of “benefit/cost ” ratio. These methods assure reliable quantitative assessments of the investment efficiency. The analysis was performed based on the following input parameters: price for unit area of collector 260 $\$/m^2$ (flat collectors) и 600 $\$/m^2$ (vacuum collectors); price of diesel oil - 0.50 $/l; annual inflation of fuel price - 10.0 %; economic appraisal life-time – 20 years; initial investment – 100 %; annual loan interest - 7.0 %; loan repayment period – 5 years; basic amortization rate - 5.0 %; operation and maintenance costs - 1.0 %; annual inflation of operation and maintenance costs - 7.0 %; tax for building improvements - 0.5 %; annual tax inflation - 7.0 %; salvage value– 50 %.

The summarized technical and economic indicators of the optimum variants of the four systems are presented in Table 1. The chosen variant from system 1 has the following economic indicators: investments - 228800 USD; profit for the life-time - 756007 USD; pay-back period - 6.9 years; “benefit/cost ” ratio BCR - 3.3

Table 1. Summarized technical and economic indicators

System	Solar collectors	Subsystem	Technical parameters				Economic parameters		
			Energy		Coverage factor				
			Consumption	Solar installation yield	Sub-system	Total	Pay-back period	Profit (LCS)	(BCR)
			GJ/year	GJ/year	-	-	Years	USD	-
1	FC	basic	2009,8	575,6	0,29	0,44	5,1	300728	4.82
	FC	peak	1568,4	1016,6	0,65		7,9	455279	2.74
2	FC	basic	2009,8	575,6	0,29	0,36	5,1	300728	4.82
	FC	peak	1568,4	711,4	0,45		6,9	344138	3.31
3	VC	basic	2009,8	465,6	0,23	0,41	9,1	201029	2.23
	FC	peak	1568,4	1016,6	0,65		7,9	455279	2.74
4	VC	basic	2009,8	465,6	0,23	0,41	9,1	201029	2.23
	FC	peak	1568,4	711,4	0,45		6,9	344138	3.31

The optimistaion procedure is hierarchical. At first stage groups of installations within each system have been compared. At second stage an analysis of the representative installations from the four system has been made..

The most applicable are indicators of the optimum variant from system 1. Table 2 shows the energy characteristics of the variant.

Table 2. Energy consumption for water heating and overall coverage factor

Indicator	Month										Total for the year
	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Consumption, GJ	187.7	02.2	367.5	28.7	544.2	544.9	530.8	277.4	203.5	188.9	3578.2
Solar installation yield, GJ	46.9	59.4	216.3	70.2	292.8	288.6	255	124	26.9	9.8	1592.2
Coverage factor f	0.25	0.294	0.589	0.511	0.538	0.53	0.480	0.447	0.132	0.052	0.445

7. INVESTMENT RISKS ASSESSMENT

The variation of the profit value LCS at variation of one of the influencing factors within acceptable limits and retaining of the rest at the same level, has been assessed. The assessment covers the parameters: initial investment; loan interest for installation construction; energy prices increase. The results are shown on the following figures.

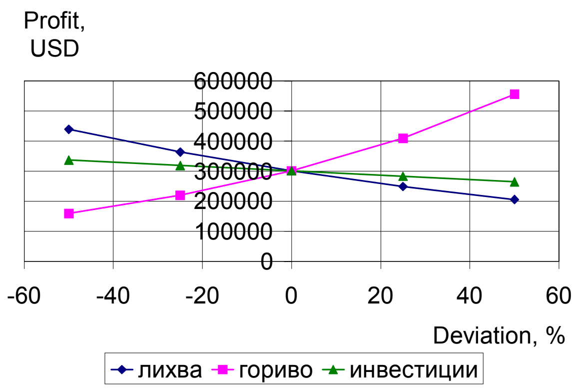

Fig. 7. Risk analysis – Systems 1 and 2 – basic installation

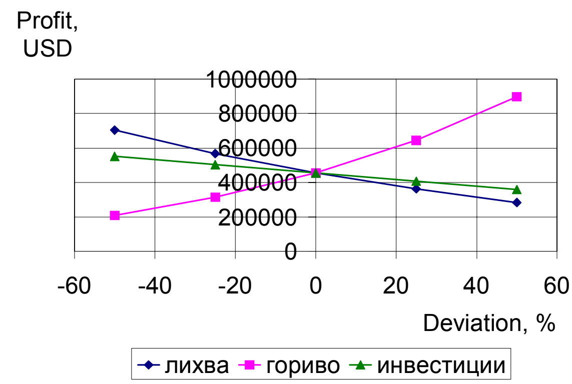

Fig. 8. Risk analysis – Systems 1 and 3 – peak installation

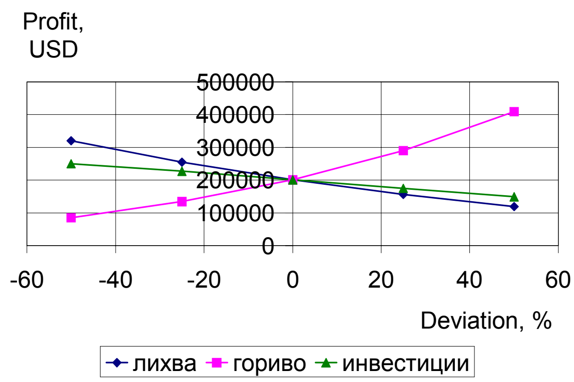

Fig. 9. Risk analysis – Systems 3 and 4 – basic installation

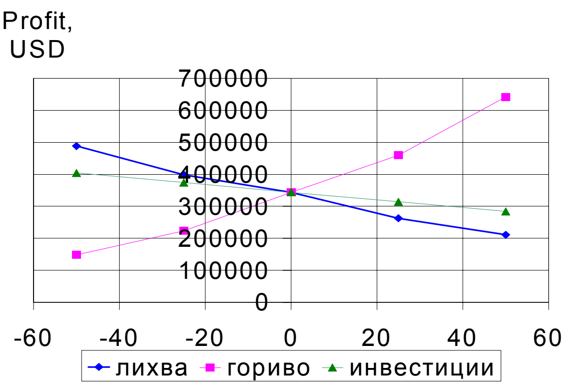

Fig. 10. Risk analysis – Systems 2 and 4 – peak installation

It can be seen that the profit is positive within broad limits of variation of factors..

Conclusion

Analyses have been made of the specifics and technical condition of installations for hot water production and consumption in the hotel complex “Dobrudzha”. Structural designs of installations have been prepared for domestic hot water preparation utilising solar energy. A multi-factor simulation analysis of solar systems energy parameters has been performed. The choice of optimum variant from System 1 is based on economic appraisal for investment and operational costs prognosis, as well as the profit during the installations life-time. It is proved that the climatic conditions in the complex make economically viable hot water production from solar installations. Prerequisites for environmental protection within Albena resort are being created.